Architectural Framework for Smart Micro-Factory

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1. Introduction

Many home based manufacturing businesses need personal attention to perform tasks associated with machines and industrial equipment. In many developed countries high cost of skilled labour enables application of automated manufacturing practices for small scale and home based businesses. In such cases monitoring of the whole plant, various objects and production units for autonomous functioning becomes essential. This paper proposes a possible solution for home based businesses to control plant that could operate autonomously in a remote mode. The proposed solution involves distributed software architecture for the micro-factory system where plant monitoring, control and management modules are distributed across the network.. Inspection tasks in the -factory control are realised using Machine Vision to detect and classify parts present in the process environment. Detection and classification is performed using Machine Vision based on evolutionary computing principles. Classification results are used for assembly and sorting operations in the plant process. Micro-factory's control subsystem is responsible for monitoring the plant using surveillance camera and Wireless Sensor Network (WSN) based system. The surveillance camera can provide real-time view of the plant for remote monitoring. The WSN monitors and assessed the health of the plant and its environment allowing for periodic adjustment of lighting conditions, temperature, humidity and air quality. The management subsystem is used to collect production data for further processing, visualization and analysis of generated results. System architecture includes local user interfaces components for micro-factory configuration and management subsystem module. In addition to local user interfaces, a smart-phone based remote (global) interface is provided as well. The aim for the presented project is to explore an architectural framework for the design of highly usable, low cost and reliable smart manufacturing system.

2. Background

This section presents our recent research in the domain of autonomous micro-factory. In addition various concepts related to mini-factory technologies, genetic algorithms (GA) in Machine Vision, WSN for plant health monitoring as well as application of web based factory control is discussed.

2.1 Smart factory a modern technological approach to manufacturing control system

One of the most recent works done by D. Zuehlke [1] provides thorough insight of fitting small size manufacturing automated plant. In this work, production process is implemented using the latest technologies in smart-phone and wireless networks. The discussed framework provides modular and portable solution for the production of coloured liquid soap. The application of Service Oriented Architecture (SoA) makes the plant globally accessible.

2.2 Wireless Sensor Network Diagnosis of Factory Health

The diagnosis of the environmental conditions of the factory is dependent upon real-time critical concerns, such as thermal overloads; and soft real-time constraints, such as non-critical alarms. A wireless sensor network implementation must cater for both hard and soft real-time criticality, in such a way that the system remains robust (through inbuilt redundancies) to system failures that are common in industrial factory environments. The system quality attributes that would feature for a wireless sensor network in a factory setting include a scalable, robust, secure and efficient system that can ensure the overall performance (data responses and delivery) is met within finite thresholds. A WSN must diagnose informational notices that include both non-critical and critical alarms. The

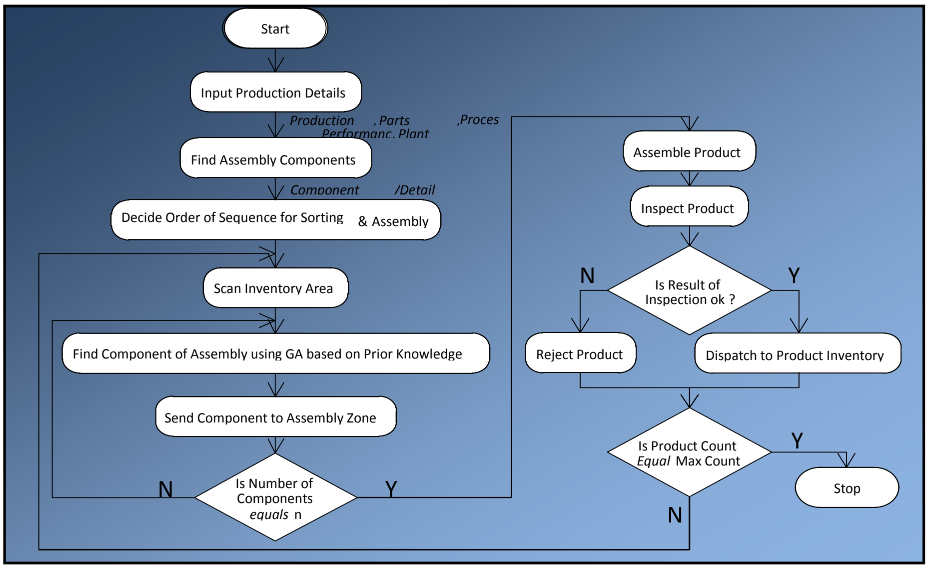

Figure 1: Smart Micro-Factory Algorithm

sensornet infrastructure supports the process of maintaining the overall health of the factory by prioritising these alarms according to criticality, not only at the logical software level but also at the protocol packet delivery level. Considering the complexity of heterogeneous factory environment, the sensor neighbourhood in WSN must cater for critical junctures in data transmission and reception. A special attention is given to the sensor's location accuracy and immunity to error propagation. This can be achieved by implementing a least mean squares filter for WSN nodes data to fit the processed information according to a generalised form in order to reduce the rate of interference in the system.

2.3 Web based control for remote and global access to plant operations of factory

Recent development in Web based applications has enabled huge opportunity for Web based surveillance and control of remotely located facility. In case of manufacturing processes remote surveillance can add great value to plant security from intrusion and accidental fault events. Recent research on remote manufacturing by several researchers' shows low level electrical signal processing and high level factory process monitoring integrated by Web based approach [2, 3, 4].

2.4 Remote Surveillance Video-streaming

Development in Mobile Surveillance systems has enhanced implementation of cost effective surveillance solutions. In case of mobile surveillance [5], [6] systems a mobile connectivity and lightweight portability is achieved by low cost setup. This type of surveillance has provided solution to many day to day life concerns including remote patient monitoring [7], car surveillance [8] and many more. Thus recent rapid developments in mobile phone platforms and broadband network availability enhance its applicability for surveillance applications.

2.5 Evolutionary for identification and classification in Computer Vision Applications

Evolutionary approach applied to Machine Vision has been the domain studied by many researchers [9]. For example, research conducted by [10] applies GA for object detection. In this case scale, rotation and translation variance is achieved by perceiving these parameters as genes of every chromosome in population. In this paper, optimization rate depends on resolution level of genes. Especially achieving object rotation accuracy may cause serious delay in optimization as 360° can involve a massive search space that depends on the object's scale. The core Web Services (WS) hosted in the smart factory architecture is running on a standard Internet Information Services (IIS) web server setup, which is standard for MS Windows 7 Professional and Windows Server 2008 Standard edition. Furthermore, the IIS web server also contains ASP.NET (Active Server Page) web application container libraries to enable hosting of the web services developed in Visual Studio 2010 to be easily deployed and integrated in the server environment using the Visual Studio IDE.

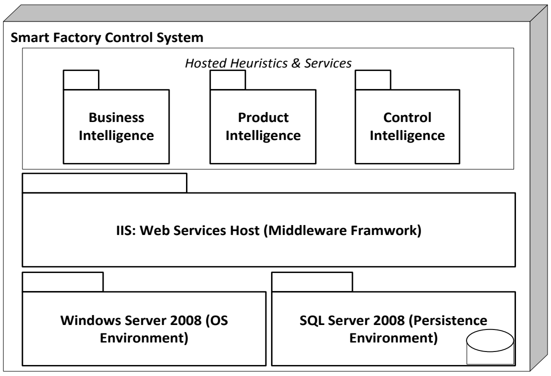

Figure 2: Micro-factory - conceptual view

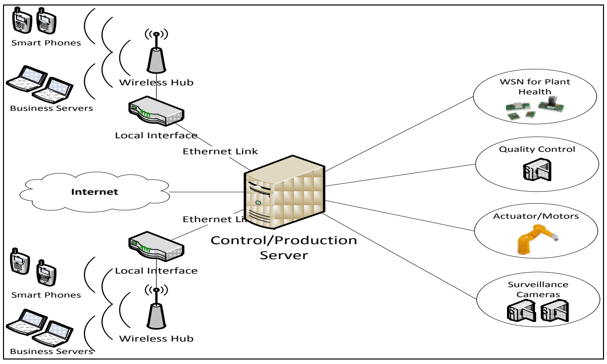

Figure 3: Distributed Environment – deployment view

3. Micro Factory Design – Case Study

In this section System Design for the entire micro plant is discussed briefly. System design includes discussion on Factory Algorithm that captures the steps of the production process, its important architectural components and design aspects.

3.1 Algorithm for Smart Factory

Based on requirement analysis of scenario algorithm (Fig. 1) was developed where the main process starts with production details input. In first step, user inputs require product details regarding the schedule from remote or local user interface. Based on these details the product components in an assembly of a particular product are located from knowledge base by the next module. Based on component details of a product sequence on operations for assembly is derived by next section of Algorithm. Once the initial analytical processing is over, the smart micro-factory is aims to complete the task of scanning the inventory area for product components. First these components need to be identified and classified, then they are conveyed to the assembly area. Once assembly is performed the rejection or quality check activities are performed. Finally, the finished product is placed in its inventory location.

3.2 Conceptual and Deployment View of the Micro-Factory

The .NET web service container provides a layer of abstraction from the user to ensure the focus of the smart factory development is on the design and implementation, not the standard configuration aspects which are preconfigured by the operating environment. The SQL Server 2008 database runs on the hosted smart factory environment in developer mode using the Open Database Connectivity (ODBC) standard, with the ODBC.NET managed data provider connecting the web service application with the persistence elements as shown in conceptual view of the system architecture (Fig. 2). Therefore, standard security and authentication measures are placed for developer and system architectural purposes, thus ensuring that the Windows Authentication mode is set to allow for authorised smart factory web-services with the correct security credentials to access non-essential and critical factory data for processing and analytical requests by the end user in distributed system environment (Fig 3).

3.3 Physical Layout

The plant area with all process components is divided in three different sections called inventory, Inspection and Assembly respectively (Fig. 4). The Inventory area stores product components and units of finished product. Inspection section is dedicated to quality testing tasks of the finished products and transportation of parts to and from inventory and assembly section. Assembly section is an area of product assembly. Process modules 5 and 9 are Delta type Parallel robots for picking and assembly. Cameras represented by modules 4 and 8 perform recognition and inspection of items after their assembly to ensure their final quality. Cameras 12 and 1 are dedicated for monitoring of assembly operations and factory surveillance, respectively. Modules 2, 3 and 10 are storage areas for finished products, product sub-components and rejected components, while modules 7 and 8 are

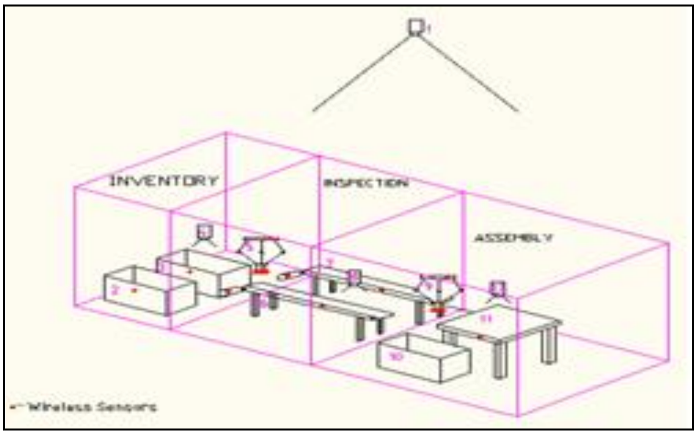

Figure 4: Layout of smart micro-factory

conveyor belts to deliver components and finished products to different sections of the factory. The workbench with identification number 11 is the assembly workbench.

4. Conclusion

Smart micro-factory is an integration platform of many subsystems involving Wireless Sensor Network, Machine Vision, Parallel Robots and Conveyors. Its main purpose is to provide fully automated solution at moderate costs to a single owner proprietary company or a hobbyist type of a user. With work done so far all subsystems gathered from different vendors are loosely coupled and needs a more specialized approach. This specialized approach intends to improve overall productivity and plant space management. Future work will involve further enhancements of the evolutionary approach applied to Machine Vision component of the system.

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